Sexual Reproduction In FLOWERING PLANTS

* Diversity in structures of → inflorescences, flowers, floral parts → shows amazing range of adaptation → to ensure End products of Sexual Reproduction → seeds, fruits (which are)

Seat of sexual reproduction

FLOWER - A FASCINATING ORGAN OF ANGIOSPERM

* Flowers are object of → aesthetic value, ornamental ", social ", religious ", cultural ", → they have been used as a symbol for conveying human feelings → love, affection, happiness, grief, mourning

* To biologist, Flowers are → morphological marvels, sites of sexual Reproduction, embryological marvels

PRE-FERTILISATION : STRUCTURES & EVENTS

* Much before the actual flower is seen on a plant → decision that the plant is going to flower has taken place.

decision → are initiated → hormonal changes, structural changes → which lead to → development, differentiation → of Floral primordium → in inflorescence are formed → which bear → Floral Bud → then → flowers → develop different male repr. struct., female reprod. structure

Stamen, Microsporangium & Pollen Grain

2 parts

Filament
- long
- slender

Anther
- Generally bilobed

* Proximal end of filament attatched to Thalamus / Petal of the flower

* 1) Number 2) Length of stamens → Variable in flowers of different species.

Typical angiosperm anther → Bilobed (each lobe having) → 2 theca (dithecous)

Bilobed nature (very distinct in) → Transverse section of anther

Longitudinal groove runs lengthwise → To separate theca

→ Four sided structure (TETRAGONAL) consisting → 4 microsporangia (located at corners → 2 in each lobe)

Pollen sacs ← develop further & become ← (all the length of anther) Run all the way longitudinally & packed with pollen grains

STRUCTURE OF MICROSPORANGIUM

* In a transverse section microsporangium → Nearly circular in outline

Surrounded by → 4 wall layers: epidermis, endothecium, middle layers, Tapetum

outer 3 → help in protection

dehiscence of anther to release pollen grains

Cells of tapetum are → dense cytoplasm, polyploid (more than one nucleus)

→ nourishes developing pollen grain

* When anther is young → group of compactly arranged homogenous cells (called) Sporogenous tissue → occupies → Centre of each microsporangium

MICROSPOROGENESIS

Cells of sporogenous tissue → undergo meiotic division to form → Microspore tetrads

each cell of sporogenous tissue → capable of giving rise to microspore tetrad

each one is → potential pollen OR MMC (microspore mother cell)

microsporogenesis (simultaneous) → microspores

as they are formed → arranged in tetrad (cluster of 4 cells) (microspore tetrad)

As anthers ① mature & ② dehydrate → Microspore dissociate from each other

1 microsporangium → inside each microsporangium → several X1000s microspores/pollen grains → released with dehiscence of anther

X1000 pollen grains

4 microsporangia → X4000 pollen grains

Pollen grains ← develop into ← Microspore

Pollen Grain: Represent the male gametophyte.

Hibiscus anthers opened → Yellowish pollen grains

* Different species of pollen grains have different → sizes, shape, colours, design
* Pollen grain has → generally spherical, 25 - 30 µm diameter, Prominent 2-layered wall

Exine

- Hard, Outer
- Made of: Sporopollenin
  - most resistant organic material
    - can withstand
      - high temp.
      - strong acids, alkali
    - can't be degraded by any enzyme.
- This layer has prominent aperture called Germ pores
  - Sporopollenin absent here
- Pollen grains can be well preserved bcz of → Sporopollenin
- Exine exhibits → fascinating array of patterns, designs

Intine

- Inner
- Thin
- Continuous
- Made of → cellulose, pectin

- Cytoplasm of pollen grain → surrounded by → Plasma membrane
- When pollen grain mature it contains 2 cells

Vegetative cell

- Bigger
- Abundant food reserve
- Large irregular shaped nucleus

Generative cell

- Small
- Floats in → Cytoplasm of vegetative cell.
- Spindle shaped cell
- nucleus

* Pollen grains shed at → 2 celled stage → in 60% of angiosperm
* " shed at → 3 celled stage → rest 40% of "
  - 1 generative → male gamete, male gamete
  - 1 vegetative

* Pollen grains of many species cause → severe allergies, Bronchial afflictions → leading to chronic afflictions/respiratory disorders → asthma, Bronchitis

* Cause pollen allergy (Ubiquitous occurence) → Parthenium / Carrot grass came into India as contaminant with imported Wheat

* Pollen grains → rich in nutrients

* Fashion in recent years to use Pollen tablets as food supplement

* In western countries → large no. of Pollen products in form of tablets, syrups → available in market

* Pollen consumption has been claimed to ↑↑ performance of athletes, race horses

* Once they shed they have to land on Stigma before they lose their viability if they have to bring fertilization

Period for which pollen grain remain viable → highly variable
- depends on: Humidity prevailing, temperature
- Rice, Wheat (cereals) → viable for 30 min
- Rosaceae, Leguminosae, Solanaceae → viable for months

* Possible to store pollen grains of large no. of species for years in liquid N_2 (−196°C)
- Such pollen can be used as Pollen Banks (similar to seed banks) in Crop breeding programmes

PISTIL, MEGASPORANGIUM (OVULE) & EMBRYO SAC

Gynoecium represents → Female Reproductive Part of flower.

Pistil → 3 parts

Stigma	Style	Ovary
Landing platform of pollen grains	• elongated • slender • Beneath stigma	• Basal • Bulged

Ovary → inside ovary → Ovarian cavity (locules) → inside this → Placenta → give rise to → Megasporangia (ovule commonly called) → no. of ovules: one (wheat, paddy, mango); many (Water melon, Papaya, Orchid)

Monocarpellary
- Single pistil
- archesporium differentiate here.
- Central tissue in nucellus (MMC / archesporium) differentiate.

Multicarpellary
- more than 1 pistil
- Syncarpous (fused) → Papaver
- Apocarpous (free) → Michelia

Megasporangium (OVULE) → Typical angiosperm ovule → anatropous

- Ovule (small structure) attached to Placenta by means of stalk – Funicle
- Ovule body fuses with Funicle at HILUM
- * Junction b/w ovule & funicle → hilum
- * Each Ovule has one or two → Protective envelops called Integuments
- Integuments encircle nucellus
- Micropyle (small opening) except at the tip
- Opposite end of micropyle → Chalaza → Basal part of ovule
- * ~~Enclosed within~~ Integuments a mass of cells → Nucellus
- cells of nucellus have abundant food reserve
- Nucellus located inside this is Embryo sac (Female Gametophyte)
- an Ovule generally has single embryo sac
- megaspore formed from

MEGASPOROGENESIS → Process of formation of Megaspore from MMC.

- Ovules generally differentiate a Megaspore mother cell (MMC) (in micropylar region of nucellus)
- Large cell, dense cytoplasm, prominent nucleus
- MMC undergoes meiosis → 4 megaspores
- (Other 3) degenerate
- Functional megaspore ← one of the megaspore

FEMALE GAMETOPHYTE

In majority of flowering plants

- develops into Female Gametophyte (embryo sac)
- Monosporic – method of formation of a embryo sac from single megaspore.
- Nucleus of megaspore divides mitotically to form 2 nuclei
- nuclei move to opposite poles
- mitotic division here – strictly free nuclear – not followed immediately by cell wall formation
- 2-nucleate embryo sac forming
- 2 more sequential mitotic nuclear division to form
- 4 nucleate
- 4 nucleate stage
- after this stage → cell walls are laid down leading to form of Typical Female Gametophyte (embryo sac)
- 8 nucleated, 7 celled
- cells organised into
- 6 nuclei (surrounded by cell walls)
- 2 nuclei (not surrounded by cell walls) → POLAR NUCLEI
- Situated below egg apparatus in Large central cell

Characteristic distribution of the cells

3 celled Egg apparatus grouped at Micropylar end.

2 synergids — have special cellular thickenings called Filiform apparatus — Imp role in Guiding Pollen tubes into synergids

1 egg cell.

3 cells at Chalazal end → Antipodal cells

1 large central cell → has 2 polar nuclei

POLLINATION

Both gametes – non-motile (Have to be brought together for fertilisation)

Mechanism to achieve this

- Pollination – Transfer of pollen grains (shed from anther) → to the → Stigma of pistil
- Flowering plants → have evolved amazing array of adaptations to achieve pollination.
  - Make use of external agents to achieve

KINDS OF POLLINATION (Depending on → source of pollen)

Autogamy

- Achieved within → same flower
- Transfer of pollen grain from anther → to → stigma (of same flower)
- In normal flower which → opens → anther & stigma → exposes
  - → complete autogamy is rare.
  - In such flowers: ① Synchronisation required in → pollen release & → stigma receptivity
  - ② Anther & stigma should lie close for self pollination to occur

Eg. → Viola (common pansy), Oxalis, Commelina

produce 2 types of flowers

- Chasmogamous – exposed anther & stigma
- Cleistogamous – do not open

* When anthers dehisce in → flower bud, pollen grain comes in contact with stigma → to effect → Pollination

Geitonogamy

Transfer of pollen from anther → to → stigma of another flower → on → same plant

Functionally & Cross pollination (involving pollinating agent)

Genetically: Autogamy (bcz of same plant)

Xenogamy

Transfer of pollen grains from anther → to → stigma of different plant

Only pollination, which brings genetically different type of pollen grain → to → stigma

Cleistogamous flowers → invariably autogamous → as → there are no chance of cross pollen landing on stigma

produce → assured set seed → even in → absence of pollinators

Agents of Pollination → Plant uses 2 types of agents

- Abiotic factor → used by small proportion of plants
  - Wind (more common)
  - Water
- Biotic Factor → used by majority of plants
  - Animals

In both: Pollen grains coming in contact with stigma is a chance factor; to compensate for uncertainty & associated loss of pollen

Flowers produce → Enormous amt. of pollen when compared to the no. of ovules available for pollination.

By WIND → more common amongst → abiotic pollination

- requires POLLEN GRAIN → light, non-sticky {so they can be transported by wind currents}
- often posses → Well exposed stamens → so that → Pollens are easily dispersed into wind currents
- Large, Feathery stigma → to → Easily trap air-borne pollen grains.
- wind pollinated plants usually have → Single ovule in each ovary
- Numerous flowers packed into inflorescence

Eg. Corn cob → (Tassels) are → style, stigma → waving in wind → to trap pollens

Wind pollination common in → Grasses

By WATER → Quite Rare in flowering plants

Limited to about → 30 genera → mostly → Monocots

Against this recall → Water is regular mode of transport for male gametes in algae, Bryophytes, Pteridophytes

their distribution is limited because of need of water for transport of male gametes for fertilization

★ WATER POLLINATED PLANTS
- Fresh waters → Vallisneria, Hydrilla
- marine → Sea grasses (as Zostera)

* Not all aquatic plants — water pollinated
* In majority of Aquatic plants → Water hyacinth, Water Lily → Flowers emerge above sea level of water → then pollinated by Insects / Wind

VALLISNERIA → Flowers reach Surface of water by long stalk
→ male flowers / pollen grains released on surface of water → carried passively by Water currents → some reach Stigma of female flowers

SEA GRASSES → ♀ flowers remain submerged in water
→ Pollen grains released inside water → long, ribbon like, carried passively inside water → some reach stigma cause pollination

* In most of the Water pollinated species → pollen grains protected from Wetting by mucilaginous coating

* Both → Wind pollinated plants, Water pollinated plants → ~~colourful~~, ~~produce nectar~~

ANIMAL POLLINATED — used by majority of flowering plants

example: Bees, Butterflies, Flies, Beetles, wasps, Ants, moths, Birds (Sunbirds, humming birds), Bats

common pollinating animals

* Among animals → Insects (Particularly : Bees) → Dominant Biotic pollinating agents

* Even larger animals have been reported as pollinators → primates → lemurs; arboreal rodents (Tree dwelling); Reptiles → gecko lizard, garden lizard

Often → Flowers of animal pollinated plants specifically adapted for a particular species of animal

* Majority of Insect pollinated flowers → large, colourful, fragrant, Rich in nectar

* When flowers are small → a no. of flowers packed into Inflorescence to make them Conspicuous

Animals → are attracted to → flowers → by → colour, fragrance

Flowers → pollinated by → flies, beetles → } secrete → foul odours → to attract those → animals.

To sustain → animal visits → flower have to provide → Rewards → Nectar, Pollen grains → for having rewards

Pollen grains → gets coated with → Body of animal ← { anther, stigma } ← animal visitor comes in contact with

Pollen grains → generally sticky (in animal pollinated flower) → When animal carrying pollen on body → comes in contact with → Stigma → pollination occurs

- In some species → Floral rewards → are → providing safe places to lay eggs

  Example → Tallest flower (Amorphallus)
  Flower – 6 ft tall

- Moth & Yucca → both species cannot complete their life cycle without each other.

  Moth → by → Flower, gets pollinated ← Locules of ovary ← in ← eggs ← Moth deposits

  Larvae of moth → comes out of → eggs → as → seeds start developing

* Many insects → consume → pollen, nectar → } without bringing → pollination
  → Bombinus affinus

Outbreeding Devices:

Majority of flowering plants → produce → hermaphrodite flowers

Pollen grains are likely to → come in contact with → Stigma of same flower

→ Continued Self pollination → results in → Inbreeding Depression

* Flowering plants → have developed → many devices to discourage self pollination.

In some species

Pollen release, Stigma receptivity → ~~Synchronized~~

→ Either pollen release before stigma becomes receptive or vice-versa

In some other species

Anther, Stigma → placed at different position → so that pollen cannot come in contact with stigma

Prod. of unisexual flowers promote cross pollination

Monoecious – Castor, Maize
prevents autogamy but not geitonogamy

Dioecy – Papaya
♂ & ♀ flower on diff. plants. This cond. prevents both autogamy, geitonogamy

One more device to prevent self pollination → Self-incompatibility → Genetic mech... from

Self-incompatibility prevents self pollination ← self pollen ← to fertile ovules ← by inhibiting
- pollen germination
- pollen tube growth in pistil

Pollen Pistil Interaction: Pollination ~~guarantee~~ transfer of right type of pollen

compatible pollen of same species as stigma → OFTEN → WRONG TYPE of pollen → either other species or same plant (if incompatible self) → also land on stigma

PISTIL has ability to recognise the pollen whether of → Right type (compatible) / Wrong type (incompatible)

★ If ✓ type pollen → pistil accepts → promotes post pollination events → leads to → fertilization

★ If X type pollen → pistil rejects → by
- preventing pollen germination on stigma
- prevent pollen tube growth in style.

Ability of pistil to recognise Pollen followed by → acceptance or Rejectance } is a result of → Continuous dialogue b/w pollen grain & pistil

this dialogue is mediated by → Chemical components of pollen interacting with those of pistil

★ In Recent years → Botanists have been able to identify some → pollen & pistil interaction & components → Recognition leading to → acceptance / rejection followed by

★ Compatible pollen grain → germinates on stigma to produce → pollen tube through one of the germ pores

pollen tube ← move into ← Content of pollen grain

pollen tube grows through → tissue of stigma / style → then reaches → Ovary

Generative cell divides into 2 male gametes during growth of pollen tube

Ovary → Ovule → pollen tube enters through → micropyle → then enters → Synergids through filiform apparatus

Studies show → Filiform apparatus also at micropylar end guides entry of pollen tube

Pollen deposition on stigma to entry of pollen tube in ovule → POLLEN PISTIL INTERACTION → dynamic process

Pollen recognition → involves → followed by → promotion / inhibition

owledge gained in this area would leads to Plant Breeder in manipulating pollen pistil interaction

desired hybrids ← to get ← incompatible pollinations ← even in

* To study Pollen Germination → Dusting some pollen from pea, chickpea, Balsam, Vinca, Crotolaria on a slide containing 10% Sugar soln drop (a drop)

After → 15 - 30 min → observe slide under → Low power lens of microscope

Pollen tubes coming out of pollen grain ← You are likely to see

Breeder → is interested in → crossing different species & genera → to combine → desirable characters

Commercially superior varities ← to produce

ARTIFICIAL HYBRIDISATION → is one of the major approach of Crop improvement Programme

in such → Crossing experiments

its imp to make sure → Only desired pollen grains → used for → pollination

- Stigma is protected from contamination (unwanted pollen) → achieved by → emasculation, Bagging

* If female parent → bears → Bisexual flowers → necessary Removal of anthers (1) from flower bud (2) (before anthers dehisce) using a forceps EMASCULATION

have to be covered by ← Emasculated flowers

Bag (of suitable size) made of: Butter paper → to prevent → contamination of stigma by unwanted pollen. This process → BAGGING

When stigma of bagged flower attains → receptive → mature pollen is collected from ♂ parent → dusted on → Stigma → Flowers REBAGGED → Fruits allowed to develop

* If ♀ flower — unisexual → emasculation → Female flowers bud are bagged before it opens → When stigma receptive → pollination carried (with desirable pollen) → Flowers rebagged

DOUBLE FERTILISATION

After entering → one of the synergids → Pollen tube releases → 2 male gametes

1 male gam. → Fuses with egg cell. (gam. moves towards egg) → Syngamy → results in → Form. of Zygote (2n)

1 male gam. → 2 polar nuclei (in center) → fuses forming → Primary Endo sperm nucleus → Triple fusion

Triple fusion occurs in embryo sac. → DOUBLE FERTILISATION (Event unique to flowering plants)

After triple fusion → Central cell → turns into → Primary endosperm cell. PEC → develop into → Endosperm

Zygote → changes to → Embryo

POST FERTILISATION : STRUCTURES & EVENTS

- Post fertilisation events →
  - endosperm development
  - embryo development
  - Maturation of ovules (s) → seed (s)
  - Ovary into → fruit

ENDOSPERM

Endosperm development precedes → Embryo development.

PEC divides repeatedly forming → triploid (3n) Endosperm tissue → cells of this tissue is filled with → Reserve food materials.

Used for nutrition of the developing embryo

In most common type of Endosperm development → PEN undergoes → successive nuclear division → Free-nuclear Endosperm

This stage is called ← Free nuclei ← to give rise to

Subsequently cell wall formation occurs → endosperm becomes → Cellular.

No. of free nuclei formed before cellularisation varies greatly

Coconut water → from → Tender coconut

free nuclear endosperm (X1000s of nuclei)

Surrounding white kernel → Cellular Endosperm

EMBRYO

develops at → Micropylar end of embryo sac — where → Zygote situated

* Most Zygotes divide only after → certain amt. of endosperm formed.

this is an ADAPTATION

endosperm → to provide assured nutrition to developing embryo.

* Though seeds differ greatly, early stages of embryo development (EMBRYOGENY) similar in both

Monocotyledons | Dicotyledons

Zygote → gives rise to → Proembryo → Globular shaped → ♡ shaped → Mature Embryo

• Typical dicotyledonous embryo → consists of → embryonal axis, 2 cotyledons

• Portion of embryonal axis above level of cotyledons → Epicotyl → which terminates with → Plumule (OR) Stem tip

• Cylindrical portion below level of cotyledons → Hypocotyl → terminates at its lower end in → Radicle OR Root tip

Root cap ← covered by

• Monocotyledonous Embryo → possess only → 1 cotyledon (scutellum)

① Radicle & ② Root cap ← At lower end of embryonal axis

Lateral (one side) of the embryonal axis ← situated towards

enclosed by → undifferentiated sheath → called → COLEORRHIZA

* Portion of embryonal axis above the level of attachment of scutellum. → Epicotyl

COLEOPTILE ← called ← structure Hollow Foliar ← enclosed in ← shoot apex & Leaf primordia ← This has

SEED

→ Final product of Sexual Reproduction

→ Fertilized ovule.

formed inside → fruit.

typically consists → Seed coats | Cotyledons | Embryonal axis

Cotyledons of embryo are → Thick / Swollen → due to storage of reserve food (as in LEGUME)

Perispermic seeds → black pepper, beet

In some seeds → remnants of nucellus persistent.

① Residual ② Persistent → Nucellus → is → PERISPERM

Integuments of Ovules → harden as → Tough protective → Seed coat

Micropyle remains as small pore in seed coat → facilitates entry of O_2 & water into seeds

* As seeds mature → Water content ↓↓↓ → seeds become relatively dry (10-15% by mass) moisture

* General metabolic activity of embryo ↓↓ → embryo enters → State of inactivity (Dormancy)

if favourable cond. available: adequate moisture, O_2, suitable temp → Seeds germinate

Mature seeds may be

Non albuminous / Ex-albuminous
* NO residual endosperm as it is completely consumed during embryo development
Pea, Groundnut

Albuminous seeds
* Retain a part of endosperm. (not completely consumed during embryo development)
wheat, maize, barley, castor

* Ovule matures into Seed
* Ovary develops into fruit
both occur simultaneously
* Wall of ovary develops into wall of fruit (Pericarp)

Fleshy fruits: Guava, Orange, Mango

Dry fruits: Groundnut, Mustard

* Many fruit have evolved mechanism for seed dispersal

* In most plants → by the time fruit develops from ovary, other floral parts degenerate & fall off

* In some species (apple, cashew, strawberry) → THALAMUS contributes to Fruit formed on → FALSE FRUITS (such fruits)

* Most fruits → develop only from ovary (called) → True fruits

* Few species → Fruits develop without fertilization → such fruits are PARTHENOCARPIC FRUITS
  - Banana.

* Parthenocarpy can be induced through Application of Growth Hormone & such fruits called seedless.

Seeds offer several advantages to Angiosperm

* Since → Reproductive processes as → pollination, fertilization → are dependent on Water → hence Seed formation more dependable

* Seeds have → Better adaptive strategies for dispersal → to new habitats → & colonise new areas → to help the species

* As seedlings have → sufficient food reserve → seedlings are nourished → until they are capable of photosynthesis

* Hard seed coat provides → protection to young embryos

* Embryo being product of → Sexual Reproduction → they generate → new genetic combination → Variations → leading to

* Seeds → basis of → Our agriculture

Dehydration & Dormancy of mature seeds → crucial for → Storage of seeds → which can be used as → Food throughout year & Raise crops in next season.

* Viability periods differ greatly in different plants.
  - In few species → seeds lose viability → in few months
  - Seeds of majority of large no. of species → live for → several hundreds of years
  - Some seeds → remain alive for → hundreds of years

* Several records of very old yet viable seeds :

Oldest is of → Lupine - Lupinus Arcticus — excavated from → Artic Tundra

The seeds germinated & flowered ← After a gap of 10,000 years of dormancy

Recent record is of → Date palm - Phoenix dactylifera — discovered from → Archeological excavation at → King Herod's palace near → Dead sea.

* Orchid fruit → Each fruit contains → 1000s of tiny seeds similar in case of Orchard Striga of Fruits of parasitic species

* Ficus tree produces billions of seeds.

APOMIXIS & POLYEMBRYONY

Few flowering plants of → some species of → Asteraceae, Grasses → have evolved special mechanism to produce seeds ← without fertilization ← APOMIXIS

APOMIXIS form of → Asexual reprod. mimics → Sexual Reproduction.

Several ways of developing of APOMICTIC SEEDS

- some species → Diploid egg cell formed without fertilization & Reduction of division → develops into Embryo
  - Apple, pear
- more often → Some nucellar cells surrounding embryo sac → start dividing → protrude into embryo sac → develops into Embryo
  - Citrus, Mango

In such species → Each ovule has many embryos. → POLYEMBRYONY referred to as

Apomictics have several advantage in → horticulture, → agriculture

Date ___/___/____

Hybrid varities of several → food / vegetable crops being extensively cultivated

Cultivation of hybrids
└ has → tremendously ↑↑ productivity

---

* One problems of hybrids is that → hybrid seeds have to prod. every year.

If seeds collected from hybrids are sown

plants in → progeny will → segregate & do not maintain hybrid characters.

Production of hybrid seeds

costly / expensive
└ for farmers

But if hybrids are made into apomicts

~~Segregation of characters in hybrid progeny~~

└ Farmers can keep on using hybrid seeds → to raise → new crop after year

X does not have to buy hybrid seeds every year

born 2 inspire Date __/__/__

*Because of importance of apomixis in hybrid seeds industry

Active research is going on in many laboratories around the world to understand.

→ Genetics of apomixis and to transfer

apomictic genes into hybrids varities.